CHEMICAL COMPOSITION OF POTATOES. VIII. EFFECT OF VARIETY, LOCATION, AND YEAR OF GROWTH ON THE CONTENT OF NITROGEN COMPOUNDS[1]

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ABSTRACT

Free amino acid content, total nitrogen, extractable nitrogen, ratio of extractable to total nitrogen, solids content, and specific gravity in Cobbler, Katahdin, Kennebec, Red Pontiac, and Russet Burbank potatoes was studied. Each variety was grown in six different locations (Idaho, Maine, Pennsylvania, Wisconsin, Long Island, and the Red River Valley) during the years 1961 through 1963. The mean values for each factor, with significant differences indicated, are listed along with the high and low range, the coefficient of variation and the overall mean. The percent of total variance contributed by each of the variables and their interactions also are listed. Long Island potatoes had the highest nitrogen and amino acid content. Varietal differences were less significant. Proline was the most variable of the constituents measured. Aspartic and glutamic acids had the highest variability with respect to years grown. The effect of each variable varies from one constituent to another.

RESUMEN

Se estudió el contenido libre de amino-ácidos, el nitrógeno total, nitrógeno extractable, proporción de nitrógeno extractable y total, contenido de sólidos y gravedad específica en las variedades de papa, Cobbler, Katahdin, Kennebec, Red Pontiac y Russet Burbank. Cada variedad fue cultivada en seis diferentes localidades (Idaho, Maine, Pennsylvania, Wisconsin, Long Island y en Red River Valley) durante los años de 1961 a 1963. Los promedios para — cada factor, con diferencias significativas, se especificaron de acuerdo con la variación alta y baja, coeficiente de variación y el promedio general. El porcentaje de variación total contribuído por cada una de las variables ysus interacciones también se especificaron. Las papas de Long Island tuvieron más alto contenido de nitrógeno y amino-ácidos. La diferencia varietal fue menos significante. La prolina fue el más variable de los elementos medidos. Los ácidos aspártico y glutámico tuvieron más alta variabilidad con respecto a los años en cultivo. El efecto de cada variable varió de un componente a otro.

The importance of the free amino acid content of potatoes to nutritive value and to susceptibility to non-enzymatic browning of processed potatoes is well known. The considerable variation in the relative quantities of some constituents of the same variety grown in different years and locations (Talley and Porter 9) is not well known. Other work (Talley and Porter 8) has indicated the degree of variation in reactivity of the free amino acids towards various sugars. Further studies, not yet published, have shown large differences among free amino acids in rate and amount of reactivity toward these sugars. This reactivity is an important factor in potato processing.

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This report deals with changes in quantities of the different free amino compounds due to variety and location, and year of production. The varieties and locations selected will not represent the maximum variation that might be encountered in all possible areas and varieties, but were representative of the commercial crop grown and processed in the United States.

MATERIALS AND METHODS

The varieties of potatoes selected were Cobbler, Katahdin, Kennebec, Red Pontiac, and Russet Burbank. These varieties were grown at each of six state experiment stations (in Idaho, Long Island, Maine, Pennsylvania, the Red River Valley, and Wisconsin) in 1961 through 1963. As reported by Schwartz, et al. (4), 100-pound samples were selected and shipped to this Laboratory. Upon arrival, they were sampled, peeled, and made into a slurry with ethanol. Changes in composition during this period would be expected to be slight, based on previous experience with the effects of storage on the nitrogen constituents (Talley et al. 6, 7, 9). However, results for reducing sugar determinations on these samples were found to be unreliable due to changes occurring between harvesting and sampling. The sampling procedure was described by Porter, et al. (2). Specific gravity determinations were made on each replicate by weighing in air and water in 1962 and 1963 but were made by the P.C.I.I. potato hydrometer in 1961. Each 1961 value is the mean of several determinations on each lot. Total solids were determined by the oven method (Porter et al. 2). Preparation of extracts and the determination of total, extractable and insoluble nitrogen were carried out as described previously (6).

Analyses of the extracts for free amino acids were made by the automatic procedure of Spackman, et al. (5) as described by Talley, et al. (7). This latter paper described the method used for estimating pyroglutamic acid by isolation, hydrolysis, and determination as glutamic acid. These values were employed to estimate aspargine and glutamine. Alkali was used for hydrolysis in 1961 and acid was employed for the 1962 and 1963 crops. In the latter case, the acid hydrolysates were adjusted to pH 1.5 before placement of the column. The results of the amino acid estimations for the 1961 samples were calculated by the manual procedure (5) and automatically by use of the digitizer and computer system described previously (Porter and Talley 3). Automatic calculation was employed for the 1962 and 1963 samples.

The same potato samples and extracts were used in this study as were employed in an acid constituent study (4). To minimize effects of changes during storage of the extracts, replicates no. 1 of all samples were analyzed in random order. When these were completed, the second set of replicates was analyzed in the same order as the first set. A new random order was utilized each year. Statistical analyses, on both the fresh and dry basis, were made by a computer procedure (cf. 4, 7). Statistical data were calculated using each replicate as an individual sample. Missing plot values (Idaho Katahdins and Red Pontiacs in 1961, and Red River Valley Katahdins in 1963) were estimated by a formula which allowed an unbiased estimate of error (cf. 4). Significant differences were estimated on both the fresh and dry basis by Duncan's Multiple Range Test (1).

Results

Tables 1, 2, and 3 list the mean values for each constituent, on the dry basis, for each variety, growing location and year grown, along with the highest and lowest value found, the overall mean and the coefficient of variation. Since solids data are included, the values on a fresh basis can be calculated. Significant differences on a dry basis are indicated by lower case letters immediately after the dry basis data. Capital letters immediately below these data, indicate th significance of differences on a wet basis. In Tables 4, 5, and 6 are listed the percentages of variability associated with each factor and the interactions, calculated on both the dry and fresh basis.

Discussion of Results

The enormous amount of data collected (180 values for each constituent) could not be published in its entirety. Therefore, the more useful data have been listed. (The complete data are available from the authors upon request). The data in Tables 1-3 give a general idea of the effect of variety, location and year on composition. The high and low ranges indicate the overall variation but these are extreme values and are the exception rather than the rule. The coefficient of variation is a measure of variability not correlated with variety, location or year or their interactions and may be due in a large part to sampling and analytical errors, and may also be due to the extreme variation in nitrogen composition from tuber to tuber, hill to till, etc. The overall mean value for each constituent is included to give an indication of an average value for the commercial crop. The data in Tables 4-6 give an idea of the relative importance of each factor tested as to overall variability. The variance component estimates, for a given analysis, were totaled to give an estimate of the total variance of the components. Each component was then expressed as a percentage of the total. Negative components were not used in the total and were considered as zero percent of the total.

The statistical procedures used are only tools for measuring the uncertainty of our inductive inferences and to help us understand the results. Other statistical procedures, especially with other data from the same original population, may give somewhat different results. The results reported here should indicate the range which can be expected in the commercial crops grown in the United States. The fact that some of the varieties are not normally grown where the experimental samples were produced should be considered.

Certain correlations can be observed in the results. Almost without exception, the Long Island potatoes were in the high range of nitrogen and free amino acid contents, on a dry basis. Proline was the outstanding exception, being next to the lowest in this location (Maine was lowest). Long Island also showed the lowest solids and specific gravity. This corroborates previous observations (6, 7, 9) that the highest nitrogen content on a dry basis is found in potatoes with the lowest solids. The Pennsylvania potatoes actually contained the highest total nitrogen content and nearly the highest extractable nitrogen, but the content of individual amino acids was inconsistent. Both Long Island and Pennsylvania samples were in the higher range of asparagine contents with the latter slightly higher. Asparagine is the free amino compound present in potatoes in the highest

TABLE 1.—*Means of amino acid concentrations, by variety and location, over a three year period. Neutral and acidic amino acids.*

			Micromoles amino acid per gram potato (Dry Basis)								
Variety	Unk. #1[2]	Unk. #2	ASP	THR	SER	ASN	GASN	PRO	GLU	GLY	ALA
Cobbler	.52b[3]	.51b	16.67bc	4.45b	5.18c	108.15c	154.18c	13.06a	22.50a	2.18c	4.39d
	A	BC	A	B	C	B	B	A	A	C	D
Katahdin	.57ab	.61a	16.16c	4.36b	6.32b	133.84a	186.88a	5.89c	17.90cd	2.84a	8.02a
	A	AB	C	B	B	A	A	C	C	A	A
Kennebec	.54ab	.49b	16.32bc	3.98b	5.07c	99.24d	152.75c	5.68c	17.37d	1.88d	5.01c
	A	C	BC	C	C	C	B	C	C	D	C
Red Pontiac	.61a	.60a	18.44a	6.17a	6.56b	111.66c	174.29b	9.99b	20.43b	2.49b	7.81ab
	A	BC	B	A	B	C	B	B	B	C	B
Russet Bur[1]	.51b	.63a	17.19b	6.40a	7.94a	126.32b	177.48ab	5.98c	18.48c	2.60b	7.52b
	A	A	A	A	A	A	A	C	B	B	AB
Location[4]											
Idaho	.54abc	.53b	15.74c	5.65a	5.80c	111.99c	161.74b	6.55b	18.22cd	2.40b	7.94a
	AB	ABC	B	A	B	C	BC	B	C	B	A
Long Island	.60a	.65a	18.62b	5.97a	8.46a	139.72b	200.68a	4.29c	20.82a	3.57a	7.49a
	BC	AB	B	A	A	B	B	D	C	A	B
Maine	.58ab	.57ab	15.48c	4.68b	5.53c	88.68e	149.83b	2.41d	17.66d	2.10c	6.78b
	BC	BC	C	D	C	F	E	E	E	E	C
Pennsylvania	.60a	.59ab	19.85a	4.73b	6.29b	153.85a	195.81a	24.19a	21.09a	2.29b	5.51c
	A	A	A	BC	B	A	A	A	A	C	C

Red River	.50bc	.56ab	15.53c	4.76b	5.77c	99.24d	152.39b	5.94b	19.78b	2.06c	6.54b
	BC	AB	B	B	B	D	C	BC	B	D	B
Wiscconsin	.49c	.50b	16.53c	4.64b	5.43c	101.58d	154.26b	5.34bc	18.44c	1.96c	5.04c
	C	C	B	CD	C	E	D	CD	D	E	D
Year											
1961	.47c	.54b	22.10a	5.06a	7.35a	109.80b	156.07c	4.91c	14.83c	2.48a	7.09a
	C	B	A	A	A	B	C	C	C	A	A
1962	.55b	.54b	14.84b	4.97a	5.37c	110.44b	169.12b	12.49a	20.95b	2.31b	5.59b
	B	B	B	B	C	B	B	A	B	B	B
1963	.63a	.62a	13.93c	5.18a	5.92b	127.28a	182.17a	6.97b	22.23a	2.40a	6.97a
	A	A	C	A	B	A	A	B	A	AB	A
Range											
Low	.13	.05	8.46	2.01	2.72	41.82	69.30	.81	7.49	1.09	1.39
High	1.10	1.34	44.20	15.14	14.67	200.39	267.38	91.26	31.42	4.99	13.68
CV[5]	25.91	28.72	11.31	23.74	15.19	10.52	11.57	28.83	6.79	10.79	14.75
Overall Mean	.55	.57	16.96	5.07	6.21	115.84	169.12	8.12	19.34	2.40	6.55

[1]Russet Bur = Russet Burbank.

[2]Unk. = unknown, listed in order of emergence from column (7) and calculated as leucine equivalents; ASP = ASPartic acid; THReonine; SERine; ASN assumed to be asparagine only (treated to remove glutamine before analysis (7)); GASN contains ASParagiNe plus part of the Glutamine, calculated as asparagine (7); PROline; GLUtamic acid; GLYcine; and ALAnine.

[3]Means followed by the same letter are not significantly different from each other at the 5% level (1), lower case letters refer to dry basis and capitals to the fresh basis.

[4]Idaho = Aberdeen; Long Island = Riverhead, New York; Maine = Presque Isle; Pennsylvania = University Park; Red River =Red River Valley, East Grand Forks, Minnesota; and Wisconsin = Sturgeon Bay.

[5]CV = Coefficient of variation.

TABLE 2.—*Means of amino acid concentrations, by variety and location, over a three year period. Neutral and acidic amino acids (continued).*

	Micromoles amino acid per gram potato (Dry Basis)											
Variety	Unk. #3[2]	VAL	MET	ILE	LEU	TYR	PHE	BAL	PYR PO_4	PYR	Solids %	Spec. Grav.
Cobbler	.26c[3]	16.06c	5.12b	6.47c	3.68b	6.69c	7.49b	.55d	50.96c	19.12c	21.70	1.08445
	B	C	C	D	B	B	A	D	C	B	A	A
Katahdin	.30b	17.82b	6.29a	7.88b	4.02ab	6.52c	6.31c	1.06a	68.51ab	28.05ab	20.12	1.07688
	B	C	A	B	B	C	B	A	B	A	C	D
Kennebec	.30b	14.99d	5.03b	5.77d	2.60c	5.34d	5.63d	.44e	63.44b	25.07b	20.75	1.08107
	B	D	D	E	C	D	C	E	B	A	B	C
Red Pontiac	.25c	21.17a	6.51a	8.01b	4.15ab	7.13b	5.45d	.79c	72.05a	28.87a	18.80	1.07128
	C	B	B	C	B	C	D	C	B	A	D	E
Russet Bur[1]	.38a	20.62a	6.54a	8.54a	4.66a	7.69a	7.87a	.89b	73.34a	26.38ab	20.93	1.08241
	A	A	A	A	A	A	A	B	A	A	B	B
Location[4]												
Idaho	.33b	19.06b	5.88b	7.67b	4.34b	6.40b	7.38b	.76d	67.44b	27.95ab	21.68	1.08369
	B	B	B	B	A	B	A	B	AB	A	B	B
Long Island	.40a	23.95a	6.63a	9.68a	5.60a	11.81a	7.80a	1.01a	80.31a	31.39a	18.68	1.07201
	B	A	A	A	BC	A	B	A	A	A	E	F
Maine	.21c	16.26d	6.14b	6.34c	3.41bc	5.42c	6.34c	.55e	72.92b	27.23b	18.79	1.07205
	D	F	D	D	D	E	D	D	BC	B	E	E

Pennsyl-vania	.39a A	17.49c C	5.74b C	7.67c B	3.47bc B	5.31c D	6.07c C	.86b A	56.30c D	22.52c B	21.39 C	1.08192 C
Red River	.25c C	15.95d D	5.16c D	6.12c C	2.66c D	4.87d DE	5.44d D	.65d C	59.27c CD	21.91c B	22.05 A	1.08773 A
Wisconsin	.22c D	16.09d E	5.84b CD	6.52c C	3.44bc C	6.23b C	6.28c CD	.66d C	57.71c D	21.99c B	20.17 D	1.07791 D
Year												
1961	.36a A	18.51a A	5.92ab B	7.56a A	3.51b A	7.46a A	6.70a A	.72b B	57.72b B	22.49c C	20.42 A	1.08709 A
1962	.26c B	16.95b B	5.66b C	7.07b B	3.05b B	5.88c C	6.39b B	.72b B	67.71a A	28.61a A	20.46 A	1.07704 C
1963	.29b B	18.94a A	6.12a A	7.38a AB	4.90a A	6.69b B	6.56ab AB	.80a A	71.55a A	25.40b B	20.50 A	1.07983 B
Range												
Low	.05	8.12	.03	2.89	.96	1.99	2.60	.17	7.98	4.72	16.03	1.06026
High	.98	32.11	9.41	14.22	16.57	17.28	13.32	1.71	140.0	67.10	25.77	1.10303
CV[5]	26.17	8.84	14.66	11.63	46.79	12.42	12.27	18.14	19.95	28.01	2.66	.24
Overall Mean	.30	18.13	5.90	7.34	3.82	6.68	6.55	.75	65.66	25.50	20.46	1.07922

[1], [3], [4] and [5] see under Table 1.

[2] Unk. = see under Table 1; VALine; METhionine (includes sulfoxides); ILE = IsoLEucine; LEUcine, TYRosine, PHEnylalanine; BAL = Beta ALanine; PYR, PO_4 = glutamine treate dto convert all of it to PYRoglutamic acid before determination (7); PYR = glutamine spontaneously converted to PYRoglutamic acid determination; Solids % = solids in percent as determined by oven drying and Spec. Grav = specific gravity of potato samples.

TABLE 3.—*Means of amino acid concentrations, by variety and location, over a three year period. Basic amino acids.*

	Micromoles amino acid per gram potato (Dry Basis)										
Variety	GAM[2]	ORN	ETH	NH_3	LYS	HIS	Unk. #4	ARG	TOTAL NIT.	EXTRA NIT.	RATIO EN/TN
Cobbler	22.39b[3] A	.56b B	.52ab A	14.21d C	8.15a A	3.79b B	1.41a A	18.31a A	1218.7ab A	685.7c B	.5608 D
Katahdin	24.22a A	.26c C	.44bc B	18.41c B	6.73b C	4.37a A	1.19c B	13.15c D	1240.5a C	738.8ab B	.5968 B
Kennebec	15.50c C	.75a A	.52abc AB	18.10c B	6.19c C	3.37c C	1.22bc B	16.08b B	1232.1a B	660.9d C	.5370 E
Red Pontiac	21.71b B	.35c C	.57a AB	23.12a A	8.09a B	3.89b C	1.36ab B	13.19c D	1251.5a D	728.9b C	.5806 C
Russet Bur[1]	22.76b A	.35c C	.43c B	20.29b A	8.41a A	4.01b AB	1.48a A	13.74c C	1189.7b C	754.3a A	.6363 A
Location[4]											
Idaho	22.39a A	.47b B	.45bc BC	18.24bc AB	8.14b A	3.68c C	1.23bc BC	14.76b B	1201.4c B	691.9c C	.5810 B
Long Island	22.82a B	.37b C	.52abc BC	22.69a A	9.50a A	5.21a A	1.95a A	17.17a B	1355.1b C	840.5a B	.6221 A
Maine	18.21c D	.39b C	.42c C	19.85b BC	7.11cd C	3.52c E	1.31bc CD	13.66c D	1087.4e E	636.8d F	.5823 B

Pennsylvania	22.61a A	.70a A	.46bc BC	18.14bc AB	6.86d B	4.20b B	1.17c BC	17.46a A	1448.4a A	812.0b A	.5614 C
Red River	22.09a A	.40b BC	.58a A	17.07c BC	5.97e C	3.22d D	.94d D	12.67d C	1157.7d C	650.0d D	.5622 C
Wisconsin	19.77b C	.40b BC	.55ab AB	16.98c C	7.53c B	3.49c DE	1.40b B	13.64c CD	1108.9e D	651.2d E	.5849 B
Year											
1961	20.03b B	.46b B	.64a A	17.17c C	7.63a A	3.81b B	1.47a A	13.81b B	1211.5b B	715.4a AB	.5912 A
1962	20.31b B	.55a A	.40b B	18.81b B	7.38a A	3.68b B	1.27b B	15.39a A	1230.1ab A	720.7a A	.5868 A
1963	23.61a A	.35c C	.44b B	20.50a A	7.54a A	4.18a A	1.26b B	15.48a A	1237.9a A	705.0a B	.5690 B
Range											
Low	8.36	.09	.09	3.63	2.78	1.46	.22	7.04	862.8	346.2	.4597
High	34.16	3.92	1.63	41.24	15.12	6.89	3.49	30.80	1675.2	1050.3	.7876
CV[5]	10.56	52.90	37.32	20.09	12.96	12.78	24.35	11.82	5.65	7.12	5.77
Overall Mean	21.31	.45	.50	18.83	7.52	3.89	1.33	14.89	1226.5	713.7	.5823

[1], [3], [4] and [5]See under Table 1.

[2]GAM = *GAMma*-amino butyric acid; ORNithine; ETHanolamine; NH_3 = ammonia; LYSine; HIStidine; UNK. #4 may be tryptophan but is calculated as leucine equivalents; ARGnine; TOTAL NIT. is total nitrogen by Kjeldahl; EXTRA NIT. is nitrogen in alcoholic extracts, by Kjeldahl; and RATIO EN/TN is the ratio of extractable nitrogen to total nitrogen.

TABLE 4.—*Percent of total variance contributed by variables and interactions. Neutral and acidic amino acids.*

	DF	UNK. #1[1]	UNK. #2	ASP	THR	SER	ASN	GASN	PRO	GLU	GLY	ALA	SOLIDS %
						Fresh basis							
Replicates	1	7.7	4.2	0.0	0.3	0.0	0.0	0.9	0.0	0.0	0.3	0.7	0.0
Years	2	19.3	5.5	48.3	0.0	20.6	3.3	19.5	0.0	40.6	0.0	8.1	0.0
Locations	5	3.2	4.8	6.5	16.2	17.4	46.5	18.69	14.6	7.3	39.3	13.6	31.5
Varieties	4	0.0	7.2	0.8	36.4	28.8	12.2	14.1	5.0	18.9	20.8	29.0	17.0
YL	10	5.5	0.0	15.8	6.9	5.9	13.6	5.7	48.9	17.1	13.0	7.9	15.4
YV	8	0.0	0.0	0.0	1.6	1.8	0.7	7.4	0.0	2.2	0.4	0.0	6.0
LV	20	2.9	0.1	0.1	4.7	1.2	2.1	5.6	2.8	0.4	6.4	13.8	6.8
YLV	40	0.0	6.5	19.0	9.9	5.6	12.6	16.4	25.5	9.6	8.3	14.6	18.1
Residual	83[2]	61.4	71.8	9.5	24.0	18.7	9.0	21.8	3.2	3.8	11.5	12.5	5.3
						Dry basis							
Replicates	1	6.8	4.7	0.1	0.8	0.0	0.0	0.6	0.0	0.0	0.2	0.5	
Years	2	15.9	4.7	46.4	0.0	17.5	3.8	12.5	0.0	45.8	0.0	7.0	
Locations	5	2.3	4.3	0.0	6.3	20.9	39.3	10.4	15.7	0.0	46.3	8.9	
Varieties	4	2.7	7.8	0.0	36.6	23.8	10.3	1.1	4.8	12.7	18.5	31.8	
YL	10	6.2	0.0	22.4	3.0	8.2	11.1	13.7	50.8	24.0	10.6	4.3	
YV	8	0.0	0.0	4.6	0.0	3.7	3.6	11.4	0.0	2.0	0.3	0.5	
LV	20	4.4	2.5	2.8	8.1	2.3	8.7	7.9	1.8	2.9	4.0	17.2	
YLV	40	0.0	11.5	14.2	0.3	6.5	12.8	21.9	24.0	7.2	10.4	18.4	
Residual	83[2]	61.8	64.4	9.5	44.9	17.1	10.5	20.4	3.0	5.6	9.7	11.5	

[1]See footnote 2 under Tables 1 and 2.
[2]Degrees of freedom corrected for missing data.

Table 5.—*Percent of total variance contributed by variables and interactions. Neutral and acidic amino acids (continued).*

	DF	UNK. #3[1]	VAL	MET	ILE	LEU	TYR	PHE	BAL	PYR PO_4	PYR	SPEC GRAV
					Fresh Basis							
Replicates	1	0.0	0.0	0.3	0.0	0.0	0.0	0.1	0.0	0.0	0.7	0.0
Years	2	5.6	2.2	9.6	0.0	4.4	4.0	0.0	0.2	10.9	6.3	0.0
Locations	5	22.1	27.1	8.2	22.3	11.2	48.3	6.4	20.8	7.4	0.7	31.0
Varieties	4	9.7	22.9	29.0	22.2	24.2	8.3	34.3	51.5	12.4	5.7	18.0
YL	10	13.5	9.9	17.0	11.4	6.6	13.4	10.0	5.1	2.3	16.1	8.0
YV	8	5.7	0.2	2.1	0.0	0.0	0.0	0.0	0.6	0.0	0.0	12.0
LV	20	0.3	8.7	8.6	4.4	6.7	5.1	8.7	2.4	1.6	7.5	6.4
YLV	40	19.1	19.2	11.7	26.9	28.6	14.0	28.7	3.5	29.7	17.7	18.8
Residual	83[2]	24.1	9.9	13.7	12.8	18.4	6.9	11.8	16.2	35.7	45.4	5.8
					Dry Basis							
Replicates	1	0.0	0.0	0.5	0.0	0.0	0.0	0.1	0.0	0.0	0.8	
Years	2	5.8	1.4	0.0	0.0	8.8	3.2	0.0	0.6	7.4	3.3	
Locations	5	20.0	27.0	0.0	24.3	5.4	54.0	6.9	21.5	11.7	2.2	
Varieties	4	6.7	22.7	15.7	20.2	4.8	4.4	20.7	52.1	10.8	8.3	
YL	10	16.2	8.9	18.2	7.6	11.1	11.0	10.6	1.5	0.8	17.6	
YV	8	6.3	1.5	0.0	0.0	0.0	0.4	0.0	1.8	0.2	0.0	
LV	20	1.7	12.4	9.3	12.0	4.2	8.9	17.8	4.3	7.6	9.5	
YLV	40	17.9	17.0	32.8	23.2	25.8	11.9	29.9	2.8	30.8	17.5	
Residual	83[2]	25.4	9.2	23.6	12.8	39.9	6.2	14.0	15.6	30.8	40.9	

[1]See footnote 2 under Table 2.
[2]See under Table 4.

TABLE 6.—*Percent of total variance contributed by variables and interactions. Basic amino acids.*

	DF	GAM[1]	ORN	ETH	NH_3	LYS	HIS	UNK. #4	ARG	TOTAL NIT.	EXTRA NIT.	RATIO EN/TN
					Fresh Basis							
Replicates	1	0.0	0.0	6.1	26.4	0.2	1.8	1.1	0.5	0.0	0.0	0.0
Years	2	9.8	2.4	21.8	4.2	0.0	1.4	2.7	1.3	0.0	0.0	0.9
Locations	5	17.5	5.2	4.4	0.6	8.9	23.4	15.5	13.7	50.4	40.7	5.0
Varieties	4	34.2	24.4	1.8	8.3	22.8	7.1	7.1	35.5	2.3	6.2	31.4
YL	10	10.5	15.2	0.5	0.0	25.5	9.5	8.4	7.6	14.4	16.1	9.2
YV	8	0.0	4.4	0.8	0.0	0.0	0.7	0.0	0.3	2.6	3.5	0.1
LV	20	4.4	4.8	0.0	9.2	9.5	7.0	0.0	3.6	0.2	7.9	10.0
YLV	40	9.0	8.7	19.0	26.2	18.0	32.4	36.2	27.4	23.5	15.2	15.7
Residual	83[2]	14.7	34.8	45.7	25.2	15.1	16.7	29.1	10.2	6.7	10.5	28.0
					Dry Basis							
Replicates	1	0.0	0.0	5.5	19.8	0.4	1.8	1.5	0.8	0.0	0.0	
Years	2	11.7	2.5	19.1	3.2	0.0	1.1	1.6	1.5	0.0	0.0	
Locations	5	6.7	2.9	0.0	2.5	12.8	25.0	23.6	11.9	32.6	27.8	
Varieties	4	36.9	23.5	1.1	11.7	13.3	2.5	2.8	20.5	0.0	0.0	
YL	10	7.6	13.9	4.4	0.0	24.3	7.6	9.1	8.6	15.8	15.4	
YV	8	0.0	4.5	3.9	0.2	0.0	3.6	0.0	2.0	7.6	8.6	
LV	20	7.4	5.6	1.6	13.5	14.3	15.5	2.7	13.6	12.3	20.3	
YLV	40	12.3	8.0	20.2	27.4	18.4	27.4	31.0	25.9	22.0	15.4	
Residual	83[2]	17.3	39.2	44.3	21.7	16.6	15.5	27.7	15.4	9.7	12.4	

[1]See footnote 2 under Table 3.
[2]See under Table 4.

amounts. The next highest constituent, glutamine (PYR, PO_4 in Table 2) was also highest in Long Island potatoes but lowest in those from Pennsylvania. (GASN in Table 1 is determined from the untreated alcoholic extract (7). It contains the total asparagine and part of the glutamine in the original potato and is calculated as asparagine. PYR, PO_4 is a measure of the original glutamine since the extract was treated to convert all the glutamine to PYRoglutamic acid before analysis (7). This value is less precise than most of the other determinations.) The overall variation for glutamine was less than for asparagine. On a fresh weight basis, the comparative standing of Long Island potatoes was less definite. No location could be identified with the lowest nitrogen and free amino acid contents. Red River Valley samples were lowest on the dry basis in eleven cases and Wisconsin samples in ten cases out of 32 possibilities. Maine samples had the lowest total nitrogen, extractable nitrogen and asparagine content.

Variation among varieties was less than that among locations. Trends were more difficult to correlate with a particular variety. Russet Burbank had high nitrogen and amino acid content in most cases. Red Pontiac was not significantly different from Katahdin or Kennebec in total nitrogen. In general, Cobbler and Kennebec were low. Katahdin had the most asparagine with Russet Burbank ranking next. Table 6 shows that the five varieties had little difference in total nitrogen, indicating a minimum chance of finding a potato of higher protein equivalent content among the commercial varieties. By a small margin, Katahdin and Russet Burbank had the highest extractable nitrogen content and, as would be expected, the highest ratio of extractable to total nitrogen. Since asparagine is the free amino compound present in the largest amounts, its concentration has the greatest effect on the total and extractable nitrogen value.

Proline showed the most variability of the constituents listed, being twice as high in Cobblers grown in Pennsylvania as in any other combination. Table 4 indicates a large variation in proline due to year x location interaction. As was true of the compounds in general, proline showed more variation with location than with variety. Katahdin, Kennebec, and Russet Burbank varieties were in the low range with about equivalent contents.

Two other important amino acids of the acidic group, aspartic and glutamic acids, had the greatest variability with respect to years grown (Table 4). The effects were opposite in direction (Table 1). Some factor or factors, associated with years, appears to affect the more acid amino acids and the non-volatile organic acids (4) to a greater extent than they do the more basic amino acids. In the majority of cases, variety and location produced greater effects than the years grown but all three factors are involved in the variation of the free amino acid content and the importance of these factors varies with the amino acid being considered.

Variation associated with replication, in this study, might be a measure of the stability of each compound during storage of the slurries and extracts used. Each year the samples were processed in random order after the slurries were prepared, but all of one replicate were run before the second replicate was processed (in the same random order as the first). Thus, changes occurring after the alcoholic extracts were made, should appear as variation between replicates. On this basis, the first two unknowns are fairly unstable. The replication values indicate, surprisingly enough, that glutamine plus asparagine was quite stable during storage in refrigerated, dilute, alcoholic solutions. Methionine shows only a slight variation, probably because the methionine sulfoxides are included with the parent compound. Ammonia showed the most change with extract storage and ethanolamine was next. No definite explanation for this observation is available. Changes in ammonia could result from decomposition of glutamine but the glutamine results do not corroborate this possibility. The volatility of the two compounds may be involved and losses might occur during concentration of the extracts.

The values for percent of total variance are similar but not exactly the same on the fresh and dry basis. Interaction with the solids content may be responsible.

In summary, location, variety, year, and replication effects were all observed in this study and the effects vary from one constituent to another. These observations confirm that potatoes are one of the very variable raw materials employed in the food processing industry.

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